



- (51) International Patent Classification:
G06K 19/06 (2006.01) *G06K 1/12* (2006.01)
- (21) International Application Number:
PCT/US2014/068812
- (22) International Filing Date:
5 December 2014 (05.12.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/919,950 23 December 2013 (23.12.2013) US
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

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(54) Title: MAGNETO-MECHANICAL MARKER APPARATUS AND SYSTEM

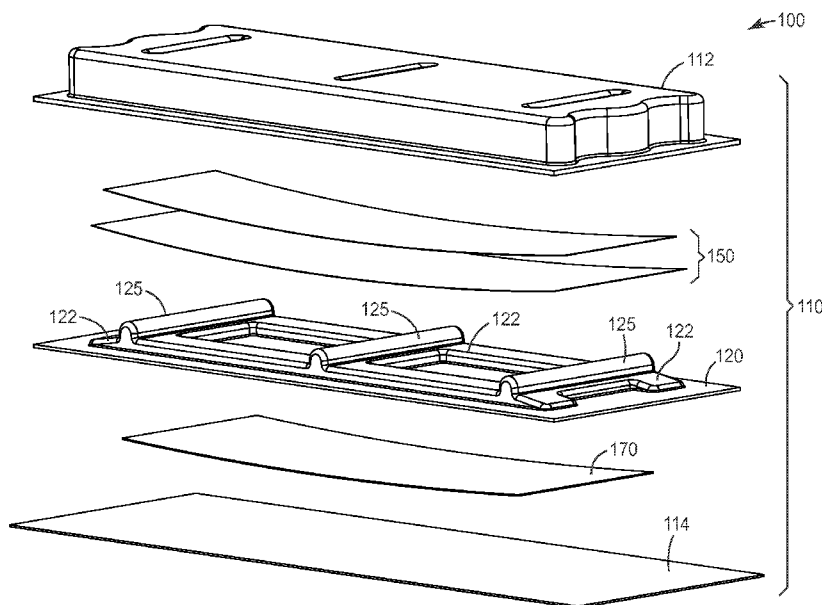


FIG. 1A

(57) Abstract: A housing for a magneto-mechanical marker comprises a base portion, a cover portion, and a separator portion disposed between the base portion and the cover portion. The separator portion provides a physical separation between at least one resonator strip and a magnetic bias, wherein the separator portion includes a plurality of spacer elements protruding towards the cover portion, the spacer elements having a curved or pointed shape in cross section configured to reduce the amount of surface contact with the at least one resonator strip.



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- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- Published:**
- *with international search report (Art. 21(3))*

MAGNETO-MECHANICAL MARKER APPARATUS AND SYSTEM

Background

5 Magneto-mechanical resonators are well known and have been used in retail security applications for decades. In addition, magneto-mechanical resonators (MMRs) are also suitable for buried infrastructure due to their low cost, low profile and flexible components. They can be stand-alone markers or physically attached to an underground pipe or utility. They can be used to identify a buried asset and its location accurately. For example, see US 2012/068823; US 2012/0325359; and US 2013/0099790, each of which
10 is incorporated herein by reference in its entirety.

Summary of the Invention

15 In one aspect of the invention, a housing for a magneto-mechanical marker comprises a base portion, a cover portion, and a separator portion disposed between the base portion and the cover portion. The separator portion provides a physical separation between at least one resonator strip and a magnetic bias. The separator portion includes a plurality of spacer elements protruding towards the cover portion. The spacer elements have a curved or pointed shape in cross section and are configured to reduce the amount of
20 surface contact with the at least one resonator strip. In another aspect, the cover portion further includes a plurality of protrusions that protrude towards the separator portion.

25 The above summary of the present invention is not intended to describe each illustrated embodiment or every implementation of the present invention. The figures and the detailed description that follows more particularly exemplify these embodiments.

Brief Description of the Drawings

The invention will be described hereinafter in part by reference to non-limiting examples thereof and with reference to the drawings, in which:

Fig. 1A is an exploded view of a magneto mechanical marker according to a first aspect of the invention.

Fig. 1B is a side, partial cross-section view of the magneto mechanical marker of Fig. 1A.

5 Fig. 1C is a side, partial cross-section view of a magneto mechanical marker according to another aspect of the invention.

Figs. 2A and 2B show distance test data for bias up and bias down samples from Tables 1-4.

10 Figs. 3A and 3B show Q test data for bias up and bias down samples from Tables 1-4.

Figs. 4A and 4B show frequency test data for bias up and bias down samples from Tables 1-4.

Figs. 5A and 5B show signal strength test data for bias up and bias down samples from Tables 1-4.

15 While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to
20 cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

Detailed Description of Embodiments

In the following description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific
25 embodiments in which the invention may be practiced. In this regard, directional terminology, such as “top,” “bottom,” “front,” “back,” “leading,” “forward,” “trailing,” etc., is used with reference to the orientation of the Figure(s) being described. Because components of embodiments of the present invention can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is
30 in no way limiting. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present

invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

A magneto mechanical resonator (MMR) marker for use in locating and identifying buried assets is described herein. Such a magneto-mechanical resonator can be suitable for buried infrastructure due to its low cost, low profile and flexible components. The MMR marker can be a stand-alone marker, it can be physically attached to an underground asset, such as a pipe or other utility, or it can be attached to another device, such as caution or warning tape, located at or near the underground asset.

Figs. 1A and 1B show a first aspect of the present invention, an MMR marker 100, in an exploded view and a side view, respectively. MMR marker 100 includes a housing 110 that encloses at least one magneto restrictive material, referred to as a resonator strip 150, and a bias magnet 170 therein. In alternative aspects of the invention, one, two, three, or more resonator strips 150 can be included in marker 100. As is understood, a conventional MMR marker is designed to couple to an external magnetic field at a particular frequency and convert the magnetic energy into mechanical energy, in the form of oscillations of the resonator strip(s). The radiated energy from the oscillating strip(s) can then be detected by a detection device.

In one aspect of the present invention, MMR marker housing 110 provides a structure for more consistent performance, especially when a non-annealed magneto restrictive material is used as the resonator strip(s) 150. In a resonator strip material that is not annealed, a down-web curl can be formed. This curl can also be affected by strip cutting or slitting. This curled shape may result in performance issues caused by damped resonance, possibly due to a varying distance between the bias magnet and the one or more resonator strips, especially at the ends of the strips, or due to rotation effects of the marker that can occur in use. Of course, MMR marker housing 110 can also house an annealed or other treated resonator strip. An annealed resonator strip material does not exhibit such a pronounced down web curl.

In particular, the housing 110 includes a base portion 114, a cover portion 112, and a separator portion 120 disposed between the base portion 114 and the cover portion 112. The separator portion 120 provides a physical separation between the at least one resonator strip 150 and a magnetic bias material 170. In an exemplary aspect of the invention, the separator portion 120 includes a plurality of spacer elements 125, formed on

pedestals 122. The spacer elements 125 protrude towards the cover portion 112. The spacer elements 125 are configured to reduce the amount of surface contact with resonator strip(s) 150. In one aspect, as is shown in Fig. 1A, the spacer elements 125 are spread apart, with a spacer elements located at the lengthwise ends of the resonator strip(s) 150.

5 In this manner, the resonator strip(s) can be suspended on a limited number of very small contact points, thus substantially reducing potential contact due to the magnetic field produced by the bias material 170 pulling the resonator strip(s) 150 against the surface of the separator portion 120. In an alternative aspect, the spacer elements 125 can be placed closer together, where each spacer element can be located near a central portion of the
10 housing 110. For example, such as shown in Fig. 1C, an MMR marker 100' can include spacer elements 125 placed closer together, where each spacer element can be located near a central portion of the housing 110.

In addition, as shown in Figs. 1B and 1C, cover 112 can include a corresponding number of downward protrusions 115 that are configured to oppose the spacer elements
15 125. With this design, even if the MMR marker is flipped upside down (from the orientation shown in Figs. 1A – 1C), the resonator strip(s) 150 can still be suspended such that there is reduced housing surface contact with the resonator strip(s).

In one aspect, such as shown in Figs. 1A and 1B, the spacer element 125 has a curved or rounded (e.g., bump) shape in cross section. Alternatively, the spacer element
20 125 can have a pointed shape in cross section. The shape and size of the spacer elements can all be the same or they can each be different. The shape and size of the spacer elements can be configured to accommodate resonator strips of different curls and lengths. Similarly, the shape and size of the downward protrusions 115 can all be the same or they can each be different. For example, as shown in Fig. 1B, the center downward protrusion
25 is slightly smaller than the end protrusions, in this case, to minimize touch points of the tag when the tag is flipped over in use (e.g, the “bias up” position – explained further below).

Resonator strip 150 comprises a ferromagnetic material with magnetostrictive properties, such as a magnetic amorphous alloy or crystalline material such as Metglas
30 2826 MB, 2605SA1 or 2605S3A made by Metglas, Inc. of Conway, S.C. Resonator strip 150 can also comprise a similar material, such as those made by Vacuumschmelze GmbH

of Hanau, Germany. The physical dimensions, such as the length, width, and thickness, of the resonator strip(s) can be chosen based on the desired response frequency.

The resonator strip material is magnetically biased by a magnetic bias material 170, such as a permanent magnet or a magnetically hard or semi-hard metal strip. A magnetically hard magnetic bias material 170 that is not readily changeable can be utilized herein because its bias characteristics are unlikely to change when buried underground. The magnetic bias layer 170 can be made from any magnetic material that has sufficient magnetic remanence when magnetized to appropriately bias the resonators, and sufficient magnetic coercivity so as to not be magnetically altered in normal operating environments. A commercially available magnetic material such as Arnokrome™ III from The Arnold Engineering Company of Marengo, Ill., can be utilized, though other materials could serve equally well. The magnetic bias layer 170 can have dimensions similar to those of resonator strip(s) 150. As with linear or bar magnets, magnetic bias layer 170 has magnetic poles, one at each end.

The housing 110, and its components, can be formed from a plastic or any other non-conductive material, such as PVC, or other polymers. In one aspect, the housing can be formed using a conventional vacuum forming process. In a preferred aspect, the housing material can maintain its shape and spacing around the resonator strip and bias material. In addition, the housing and component material can be formed as a non-rigid or flexible structure, either as a result of material composition or thickness of the housing walls. For example, the spacer elements 125 can be formed as non-rigid or flexible structures.

In a further aspect of the invention, the MMR marker 100 can be placed within a protective capsule or outer housing designed to withstand rugged conditions. The protective capsule can be formed from a rugged material such as high density polyethylene (HDPE).

MMR marker 100 can be disposed on or near an underground asset, such as a pipe, conduit, or other facility. For example, an MMR marker can be a stand-alone marker, it can be physically attached to an underground asset, such as a pipe or other utility, or it can be attached to another device, such as caution or warning tape, located at or near the underground asset. In addition, the MMR markers described herein can be utilized in non-underground environments, such as for use in locating and identifying above-ground

assets otherwise hidden from view (such as in a container or within a building wall, ceiling, or floor).

Moreover, the MMR markers can be specifically designed to operate at different frequencies which are associated with unique asset types such as different utility infrastructure (e.g., water, waste water, electric, telephone/cable/data, and gas). For example, in one aspect, the MMR marker has a frequency range of from about 34 kHz to about 80 kHz. It is noted that for some applications, for example, for plastic pipe locating, frequency shifts are not desirable where multiple MMR markers may be combined to achieve additional detection depth. Accordingly, the MMR markers disclosed herein can be clustered (for additional depth), without demonstrating substantial frequency shifts. In addition, especially for pipe locating applications, the MMR markers can be employed to provide not only asset location, but also asset directionality.

In alternative aspects, MMR marker 100 can be utilized as part of a sterilization indicator system that provides time, temperature, and/or chemical information. In a further alternative aspect, MMR marker 100 can be utilized as part of a perishable (e.g., food spoilage) indicator system that provides time and temperature information. In a further alternative aspect, MMR marker 100 can be utilized as part of a leak detection system that provides leak information for above or below ground utilities. For example, in this particular aspect, the MMR marker can further incorporate an embedded antenna to wirelessly communicate sensor information. Alternatively, the MMR marker can be designed to be physically affected by changing conditions so that a signal response may vary over time or conditions, indicating certain information to the user.

In operation, MMR marker 100 resonates at its characteristic frequency when interrogated with an alternating magnetic field tuned to this frequency. Energy is stored in the marker during this interrogation period in the form of both magnetic and mechanical energy (manifested as resonator vibrations). When the interrogation field is removed, the resonator continues to vibrate and releases significant alternating magnetic energy at its resonant frequency that can be remotely sensed with a suitable detector. Such a response alerts a locating technician to the presence of MMR marker 100.

There are several specific performance related characteristics, frequency, signal and Q, that can be optimized with the MMR marker locator system, with each having its own advantages depending upon the specific application and detection criteria. In many

applications, the orientation and rotation of an MMR marker cannot be controlled. Therefore, it is advantageous to construct and configure the MMR marker to obtain a consistent performance in all orientations.

More specifically, frequency can be impacted as the markers/resonators are allowed to move closer and farther away from the biasing field. As is understood, the magnetic near fields drop off rapidly as a function of distance ($1/r^3$). The embodiments of the invention described herein reduce the amount of distance the resonator strips can fall away from the magnetic bias material, thus minimizing this affect.

Regarding signal, as the frequency shifts, in many applications the detector may not be configured as a broad band interrogation device. In one example, for plastic pipe locating, frequency shifts are not desirable for multiple reasons where multiple MMR markers may be combined to achieve additional detection depth. Accordingly, for that implementation, minimizing frequency shifts can improve performance. Differences in the frequencies of tags that are being combined must be very close in frequency to achieve improved performance.

Regarding Q, this characteristic is a measure of how long the MMR marker/resonator strip(s) continues to resonate after the interrogating field is turned off. By reducing the surface area contact between the resonator strip and the housing, frictional forces can be reduced. Further, by suspending the ends of the resonator strip(s), there is reduced dampening of the resonance, resulting in higher Q.

In addition, the cost of locating equipment, speed of the locating device, the distance the MMR marker is positioned from the locating device, and the amount of power provided to the MMR marker all affect the system performance.

An exemplary portable locating device, such as described in US 2012/068823, incorporated by reference above, can comprise a single antenna that is used to generate an electromagnetic field and to detect a response of the MMR marker 100. In an alternative aspect, one antenna could be used for generating an electromagnetic field and a second antenna could be used for detecting the response of the MMR marker to the generated field. The locating device can be battery powered for better portability. An integrated display can provide a user with a variety of information about located MMR markers and the assets that the MMR markers are associated with. For example, the display can provide information about marker and asset depth, direction, or other information about

the MMR markers. One exemplary portable locating device is the 3M™ Dynatel™ 1420 Locator, distributed by 3M Company of St. Paul, Minn. In one embodiment, the locating device firmware can be programmed so as to tune the locator antenna to radiate a particular, or several particular desired frequencies.

5 As mentioned above, MMR marker 100 can be associated with an asset buried underground. An article including an MMR marker 100 can also be associated with an asset. An MMR marker 100 or an article including MMR marker 100 can be associated with an asset so that it is physically attached to the asset, incorporated into the asset, in the same vertical plane as the asset, whether disposed above or below the asset, or offset from
10 the asset, including being offset to the side of the asset. In some aspects, where the MMR marker or article is not physically attached to the asset, the MMR marker or article may be within a 30 cm, 60 cm or 1 meter radius of the asset. In some aspects, a single MMR marker can be used to identify an asset. In other aspects, multiple MMR markers, arranged in series, parallel, or in clusters, can be utilized. Clusters can be generally
15 arranged so that the signals from multiple MMR markers are additive.

In other aspects, the MMR markers can be oriented so the magnetic polarity of each marker's magnetic bias layer is the same. The magnetic north poles can generally face the same direction and the magnetic south poles can face the same direction as each other, and in the opposite direction of the north poles. Within a cluster of MMR marker,
20 each MMR marker can be spaced an appropriate distance from each other.

Several factors can influence a determination of the spacing distance. For example, when two markers are near each other, the magnetic bias layer of one marker can influence a neighboring marker, causing a shift in resonant frequency. On the other hand, long distances between two neighboring or adjacent MMR markers can diminish the
25 received signal amplitude advantages from grouping the tags, for example, as the locating/interrogation device may be placed outside of the range of a neighboring tag.

Experiments

30 Experiments were conducted comparing MMR markers having a spacer element design similar to that shown in Figs. 1A and 1B with MMR markers that have the same

physical dimensional distances between the bias material and the resonator strip(s), but without the additional spacer elements (see e.g., spacer elements 125).

The resonator materials were selected to operate at 41.4 kHz and were supplied by Metglas, Inc. of Conway, S.C. Each marker included two resonator strips, with a first strip
5 being 12mm wide and a second strip being 10mm wide. The length of each strip was selected based on its material properties and was approximately 53mm. The bias was approximately 47mm long.

In the first set of test samples (Test Sample 1), 10 sample metal sets, with each metal set comprising a 12 mm resonator strip, a 10mm resonator strip and a biasing
10 magnet were placed in a housing that did not include spacer elements formed on the separator layer. The test samples were first measured in a bias “down” orientation (i.e., the bias magnet is disposed below the resonator strip (such as is shown in Fig. 1A)) and then those same 10 sample markers were measured in a bias “up” orientation (i.e., the bias magnet is disposed above the resonator strip (such that the marker is flipped with respect
15 to the orientation shown in Fig. 1A)).

In the second set of test samples (Test Sample 2), the same 10 sample metal sets used in the above experiment, were each placed in a housing that included spacer elements formed on the separator layer (similar to the configuration shown in Fig. 1A). These 10
20 sample markers were first measured in a bias “down” orientation and then those same 10 sample markers were measured in a bias “up” orientation.

The separator layers for both Test Sample 1 and Test Sample 2 had a thickness of about 1.5 mm.

The following characteristics were measured. First, the detection distance was measured using a detector/locator device designed specifically for use with the tested
25 MMR markers. This measurement corresponds to the distance between the locator end and the MMR marker where the signal strength drops below a predetermined threshold that is calibrated to be 10 dB above the environment noise floor. For example, for Test Sample 1, the average detection distance is about 32 inches (81.28 cm) for bias down and 39 inches (99.06 cm) for bias up. For Test Sample 2, the average detection distance is
30 about 38 inches (96.5 cm) for bias down and 39 inches (99.06 cm) for bias up. This data indicates substantial advantages are realized in the “bias down” condition, which appears

to be more impacted by the minimized surface contact between the spacer element and the resonator strip(s).

Another characteristic measured was frequency, which corresponds to the frequency of the emitted signal from the MMR marker after excitation. For example, for Test Sample 1, the average measured frequency was about 41.6 KHz for bias down and about 41.5 KHz for bias up. For Test Sample 2, the average measured frequency was about 41.4 KHz for both bias down and for bias up. This data indicates that advantages in frequency stability can be realized from the cover protrusions (see e.g., protrusions 115) that minimize the distance the resonator strip(s) are displaced when the marker is flipped from the bias down to the bias up condition.

Another characteristic measured was signal, which corresponds to the signal strength in dB that the MMR marker is able to produce at a specific distance, in this case, a field strength that is equivalent to the marker being 30" from the locator device.

A final characteristic measured was Q-value, which corresponds to the length of time the marker continues to resonate after the alternating magnetic field provided by the locating device is removed. The Q-value also impacts the amount of energy needed to be transmitted to the MMR marker in order to maximize the signal response.

Tables 1 to 4 provide information relating to read distance, frequency, signal strength, and Q calculations for bias up and bias down orientations for each of the Test Sample sets 1 and 2. The results for these tests are shown in Figs. 2A, 2B (Distance), Figs. 3A, 3B (Q), Figs. 4A, 4B (Frequency), and Figs. 5A, 5B (Signal Strength).

A commercial function generator was used to generate the signal at a known frequency, amplitude, and was connected to a custom-wound transmit coil. The receive coil, which is disposed inside the transmit coil, was connected to an oscilloscope. The tests used an industry standard communications protocol/bus to communicate from the oscilloscope and function generator.

Table 1				
Bias Down - No Spacer	Read Distance	Frequency	Signal Strength	Q
	cm	kHz	dB	
CE1	81.28	41.408	28	188
CE2	83.82	41.408	27	190

CE3	76.20	41.714	10	99
CE4	66.04	41.582	30	253
CE5	86.36	41.625	31	364
CE6	66.04	41.769	24	199
CE7	99.06	41.699	20	176
CE8	88.90	41.462	33	291
CE9	86.36	41.35	30	244
CE10	76.20	41.59	25	182
Average	81.03	41.56	26	219
Standard Deviation	10.26	0.15	7	73

Table 2				
Bias Down - Spacer	Read Distance	Frequency	Signal Strength	Q
	cm	kHz	dB	
E1	96.52	41.221	37	315
E2	93.98	41.318	34	317
E3	93.98	41.384	28	198
E4	83.82	41.412	30	233
E5	96.52	41.466	31	287
E6	101.60	41.544	34	288
E7	99.06	41.513	38	416
E8	101.60	41.373	32	247
E9	101.60	41.241	33	241
E10	101.60	41.524	34	326
Average	97.03	41.40	33	287
Standard Deviation	5.59	0.11	3	62

Table 3				
Bias Up - No Spacer	Read Distance	Frequency	Signal Strength	Q
	cm	kHz	dB	
CE11	101.60	41.342	34	297
CE12	93.98	41.353	33	268
CE13	104.14	41.528	31	269
CE14	96.52	41.579	40	464

CE15	99.06	41.571	38	481
CE16	104.14	41.617	37	450
CE17	96.52	41.544	38	428
CE18	99.06	41.408	35	307
CE19	96.52	41.326	31	267
CE20	93.98	41.637	32	402
Average	98.55	41.49	35	363
Standard Deviation	3.75	0.12	3	89

Table 4				
Bias Up - Spacer	Read Distance	Frequency	Signal Strength	Q
	cm	kHz	dB	
E11	101.60	41.256	35	266
E12	96.52	41.264	34	263
E13	106.68	41.361	35	330
E14	93.98	41.408	33	263
E15	96.52	41.423	37	403
E16	109.22	41.524	36	318
E17	93.98	41.536	37	387
E18	99.06	41.384	32	244
E19	99.06	41.225	33	241
E20	99.06	41.528	33	288
Average	99.57	41.39	35	300
Standard Deviation	5.05	0.12	2	58

As is shown in the above measurements, the inclusion of spacer elements as an integral part of the separator layer provides better detection range independent of MMR marker orientation, more consistent frequency results when the MMR markers are flipped, better Q and better overall performance.

Thus, the MMR markers described herein can be utilized in many different identification and location applications. For example, an MMR marker can be a stand-alone marker, it can be physically attached to an underground asset, such as a pipe or other utility, or it can be attached to another device, such as caution or warning tape, located at

or near the underground asset. In addition, the MMR markers described herein can be utilized in non-underground environments, such as for use in locating and identifying above-ground assets otherwise hidden from view (such as in a container or within a building wall, ceiling, or floor).

5 The present invention has now been described with reference to several individual embodiments. The foregoing detailed description has been given for clarity of understanding only. No unnecessary limitations are to be understood or taken from it. It will be apparent to those persons skilled in the art that many changes can be made in the embodiments described without departing from the scope of the invention. Thus, the
10 scope of the present invention should not be limited to the details and structures described herein, but rather by the structures described by the language of the claims, and the equivalents of those structures.

Claims

1. A housing for a magneto-mechanical marker, comprising:

a base portion, a cover portion, and a separator portion disposed between the base portion and the cover portion, the separator portion providing a physical separation
5 between at least one resonator strip and a magnetic bias, wherein the separator portion includes a plurality of spacer elements protruding towards the cover portion, the spacer elements having a curved or pointed shape in cross section configured to reduce the amount of surface contact with the at least one resonator strip.

2. The housing of claim 1, wherein first and second spacer elements are disposed at or
10 near longitudinal end points of the at least one resonator strip.

3. The housing of claim 2, wherein a third spacer element is disposed at a position approximately midway between the longitudinal end points of the at least one resonator strip.

4. The housing of claim 1, wherein the cover portion includes a plurality of
15 protrusions formed on an inner surface thereof that protrude towards the separator portion.

5. The housing of claim 4, wherein a position of each of the cover protrusions corresponds to a position of each of the spacer elements such that the cover protrusions and spacer elements oppose one another.

6. The housing of claim 4, wherein one or more spacer elements are disposed at or
20 near a central portion of the at least one resonator strip.

7. A magneto mechanical marker comprising the housing of any of claims 1-6.

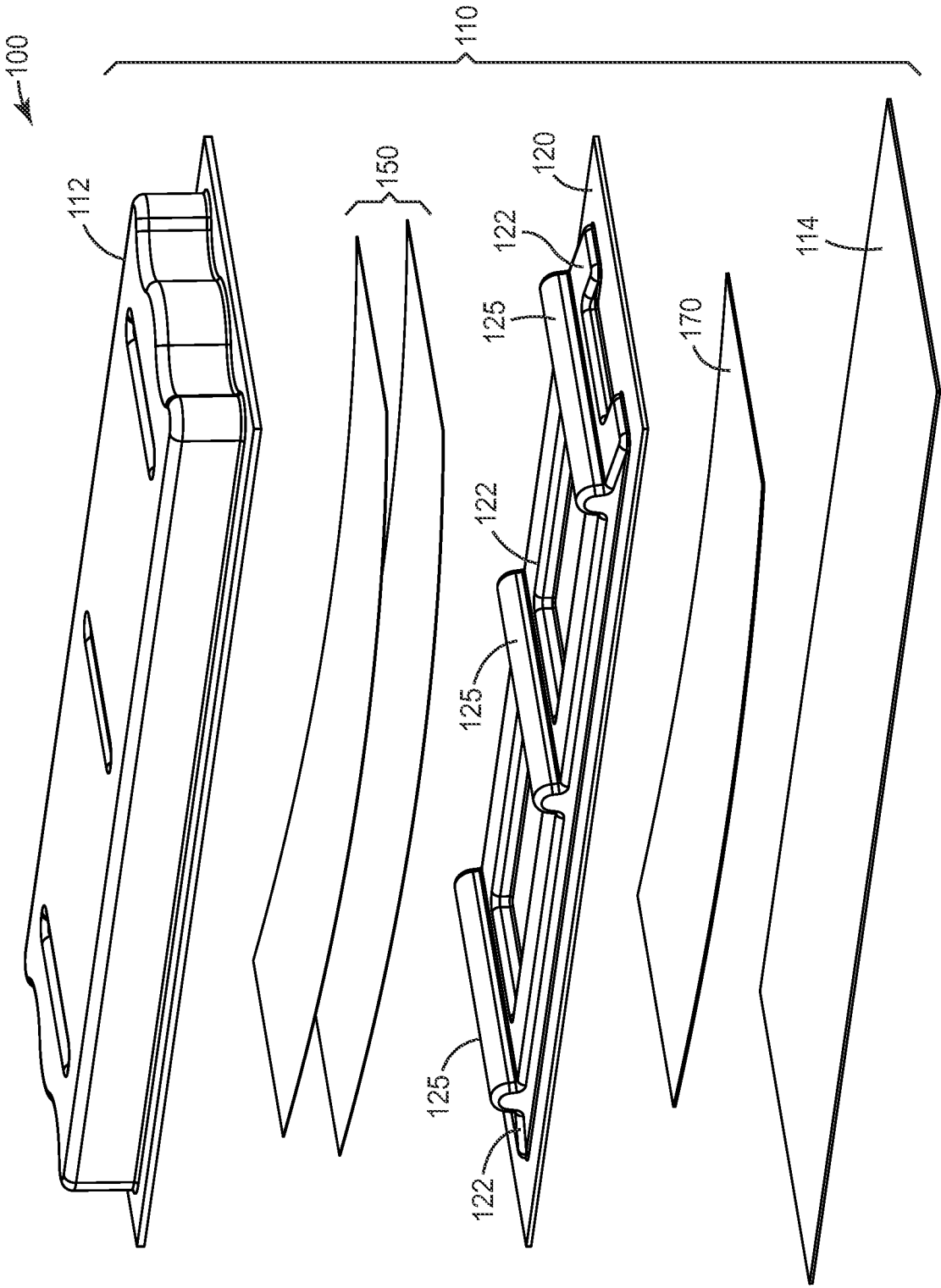
8. The magneto mechanical marker of claim 7, comprising at least one resonator strip formed from a ferromagnetic material with magnetostrictive properties.

9. The magneto mechanical marker of claim 8, comprising at least two resonator
25 strips.

10. The magneto mechanical marker of claim 7, wherein the marker has a frequency range of from about 34 kHz to about 80 kHz.

11. The magneto mechanical marker of claim 7, wherein the marker can be detected at a depth up to 40 inches underground.

5 12. A magneto mechanical marker system comprising the magneto mechanical marker of claim 7 and a portable locating device.



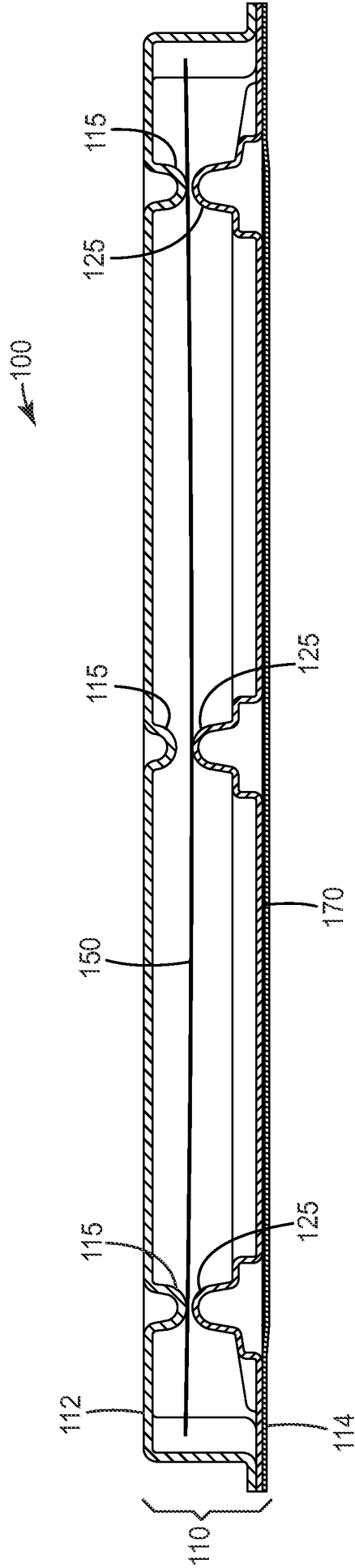


FIG. 1B

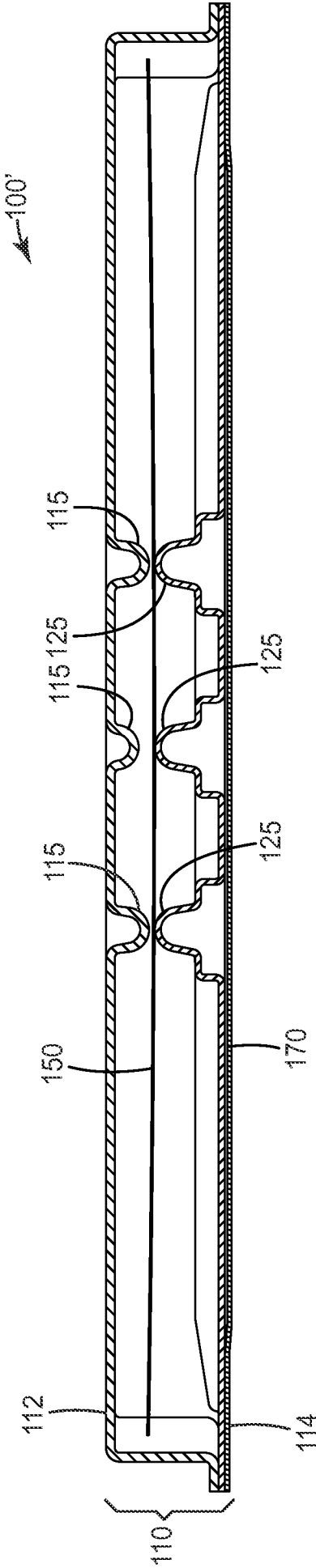
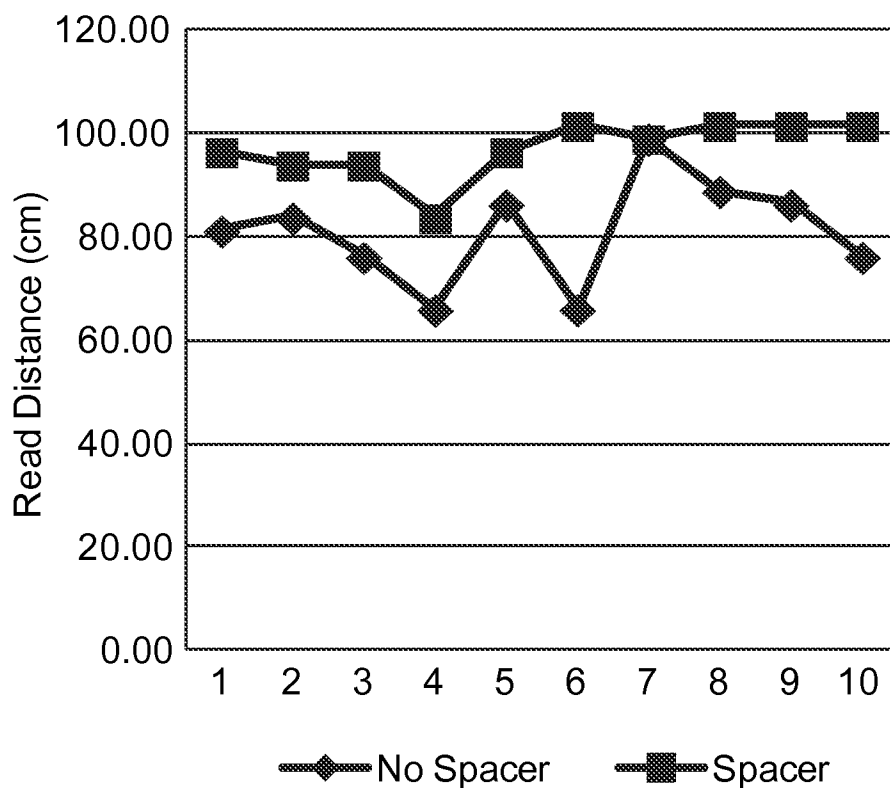
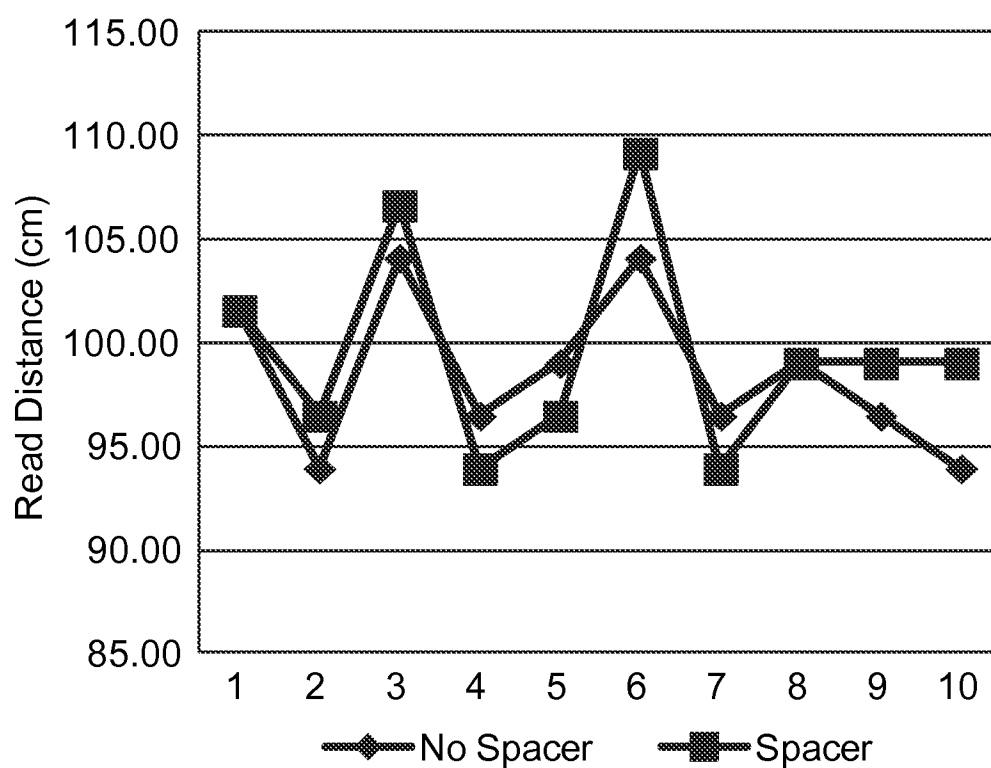
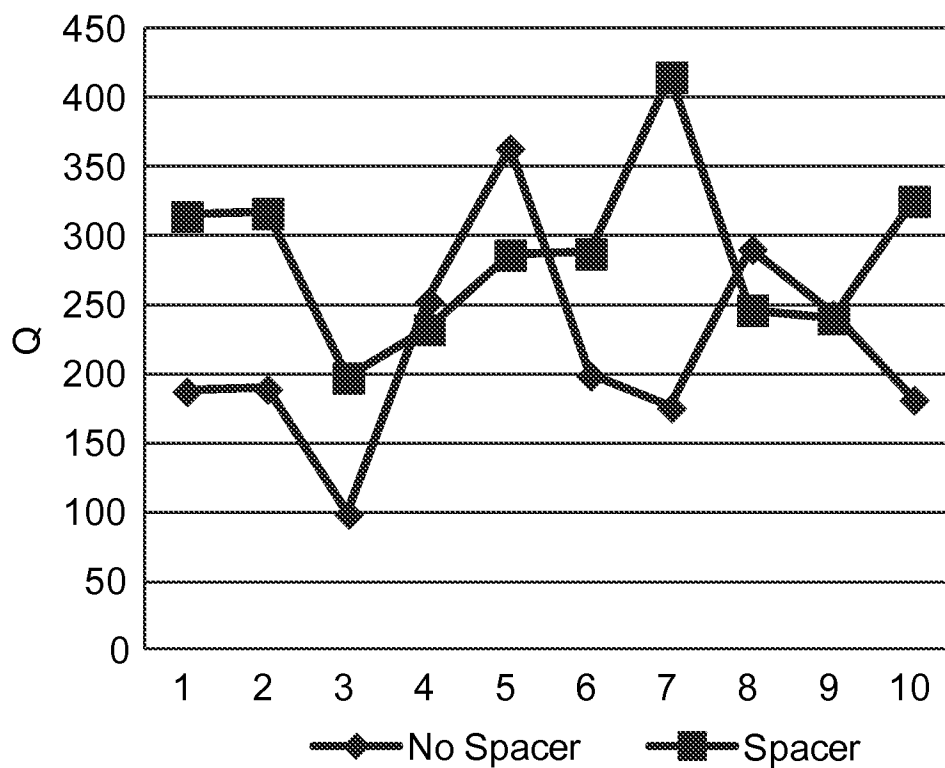
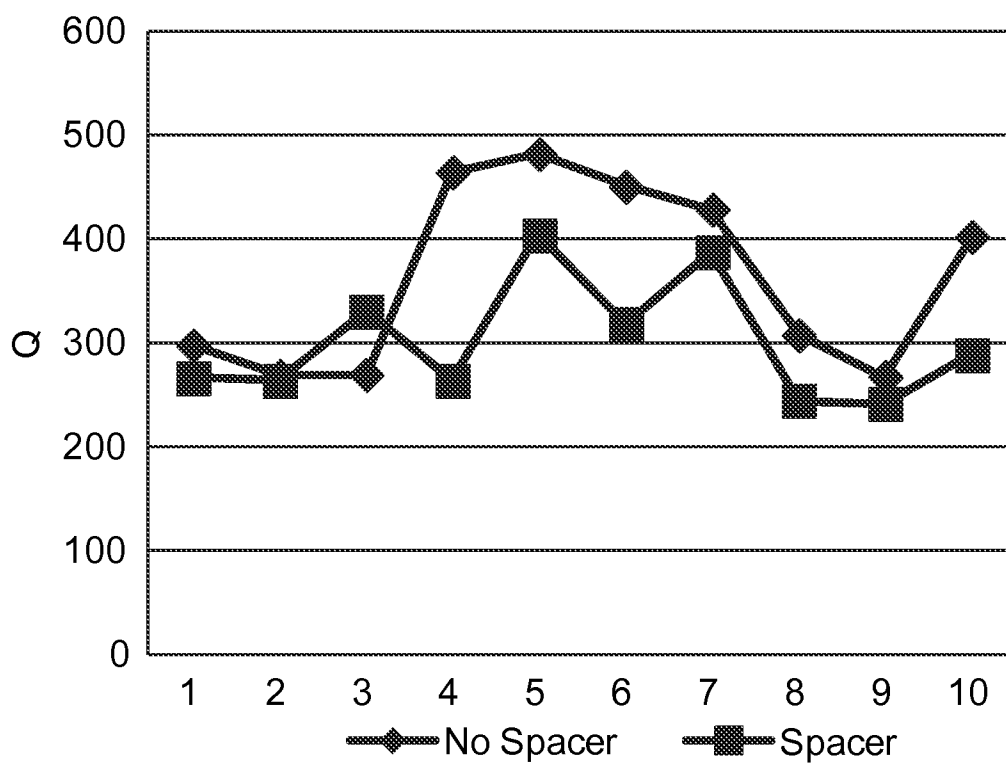


FIG. 1C

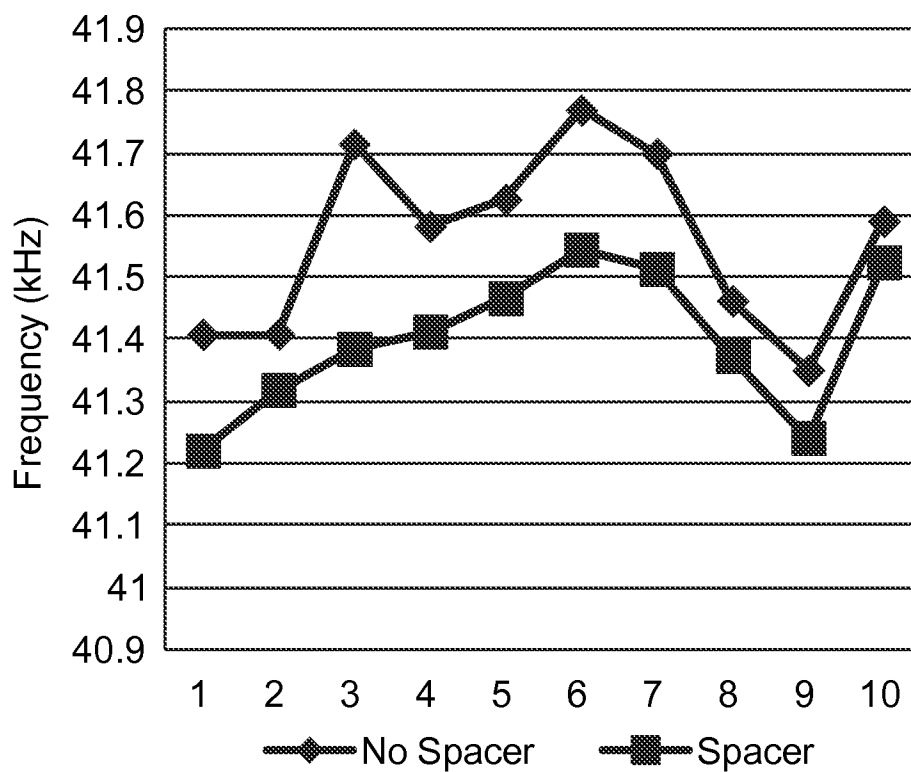
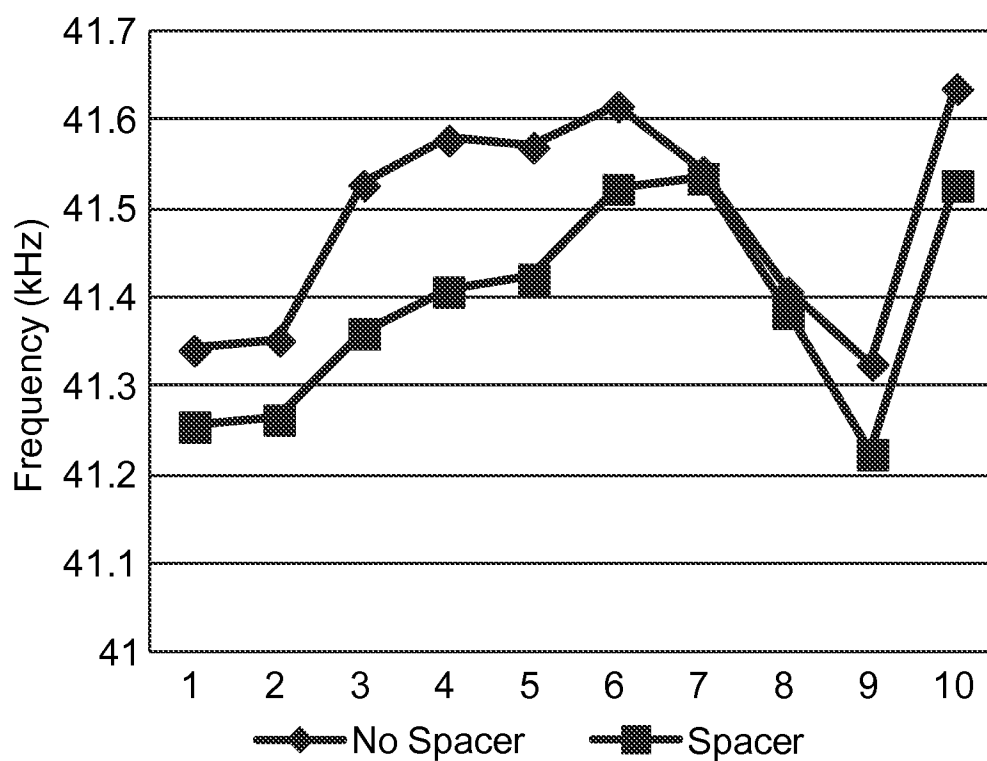
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*FIG. 2A**FIG. 2B*

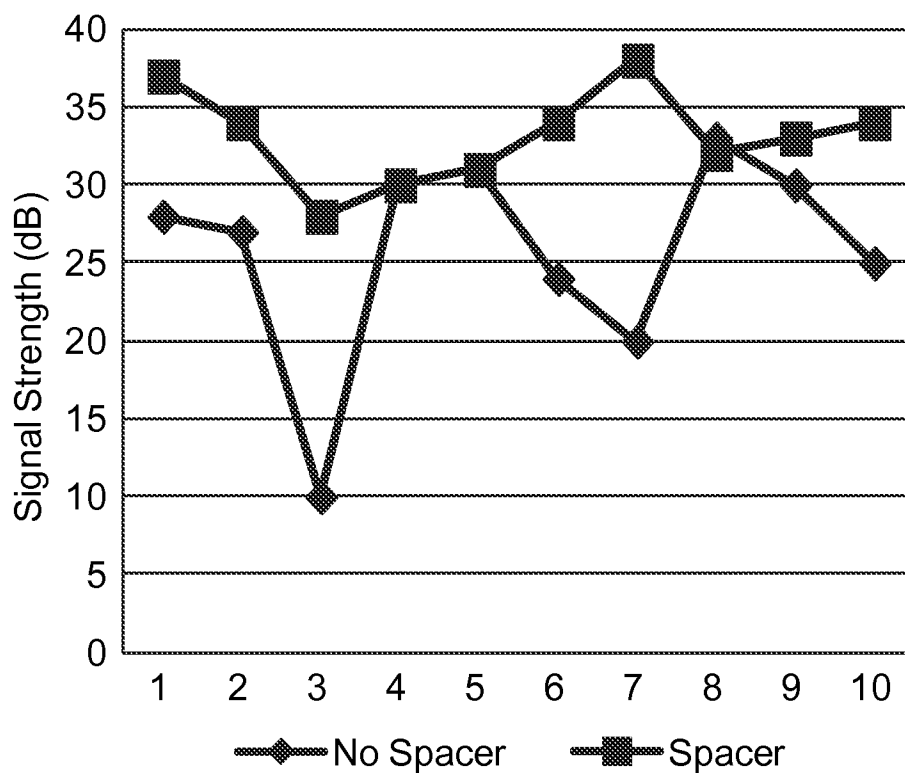
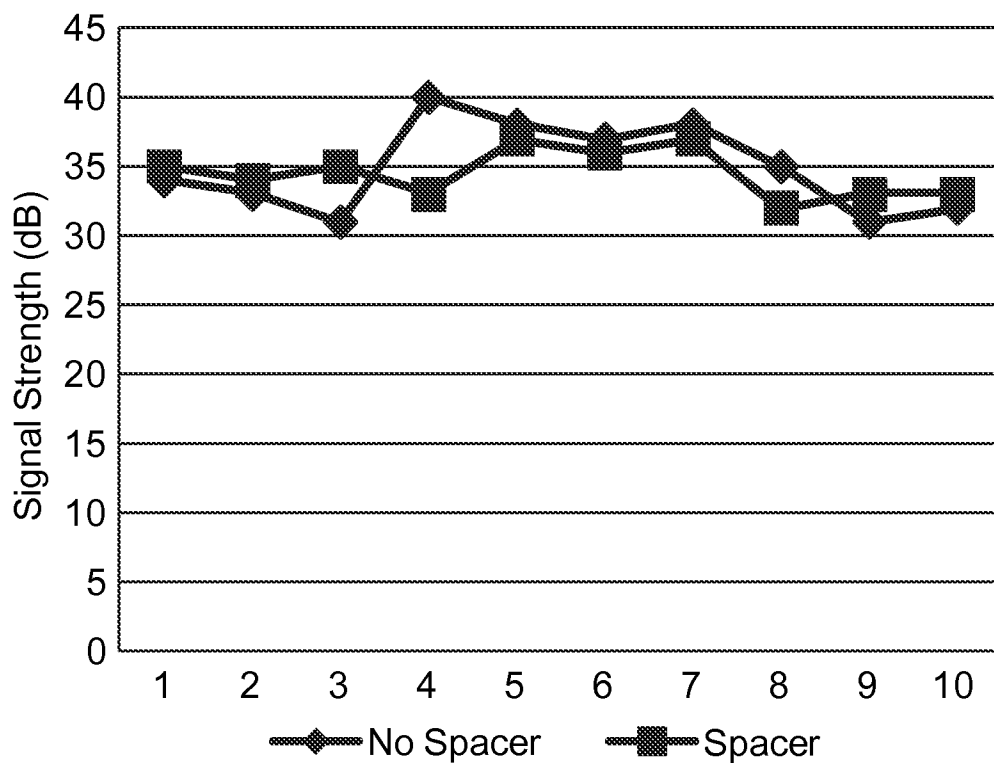
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*FIG. 3A**FIG. 3B*

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*FIG. 4A**FIG. 4B*

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*FIG. 5A**FIG. 5B*

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/068812**A. CLASSIFICATION OF SUBJECT MATTER****G06K 19/06(2006.01)i, G06K 1/12(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G06K 19/06; G08B 5/22; G01V 3/12; H01Q 21/28; G08B 13/14; H04Q 5/22; H01F 7/06; G06K 1/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords:magneto-mechanical marker, underground asset, resonator strip, magnetic bias, housing, base, cover, separator, spacer, portable locating device

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2012-0068823 A1 (ZIYAD H. DOANY et al.) 22 March 2012 See paragraphs [0011], [0027]-[0029], [0032], [0050]; and figure 1.	1-12
A	US 2009-0195386 A1 (JOHANNES MAXMILLIAN PETER et al.) 06 August 2009 See paragraphs [0018], [0039]-[0040], [0042]; and figures 2, 4.	1-12
A	US 2010-0259391 A1 (DENNIS M. GADONNIEX et al.) 14 October 2010 See paragraphs [0012], [0015], [0024]-[0025].	1-12
A	US 2002-0171548 A1 (WING HO et al.) 21 November 2002 See paragraphs [0010], [0015]-[0016], [0031].	1-12
A	US 2013-0099790 A1 (ZIYAD H. DOANY et al.) 25 April 2013 See paragraph [0004], [0006], [0043].	1-12

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

19 March 2015 (19.03.2015)

Date of mailing of the international search report

19 March 2015 (19.03.2015)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/068812

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INTERNATIONAL SEARCH REPORT

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		WO 2013-058984 A1	25/04/2013